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WORST-CASE STRESS ANALYSIS OF RECEIVER POWER SUPPLIES IN TORPED--ETC(U)
AUG 77 R GELLNER, J WEISEL N00123-76-C-0797
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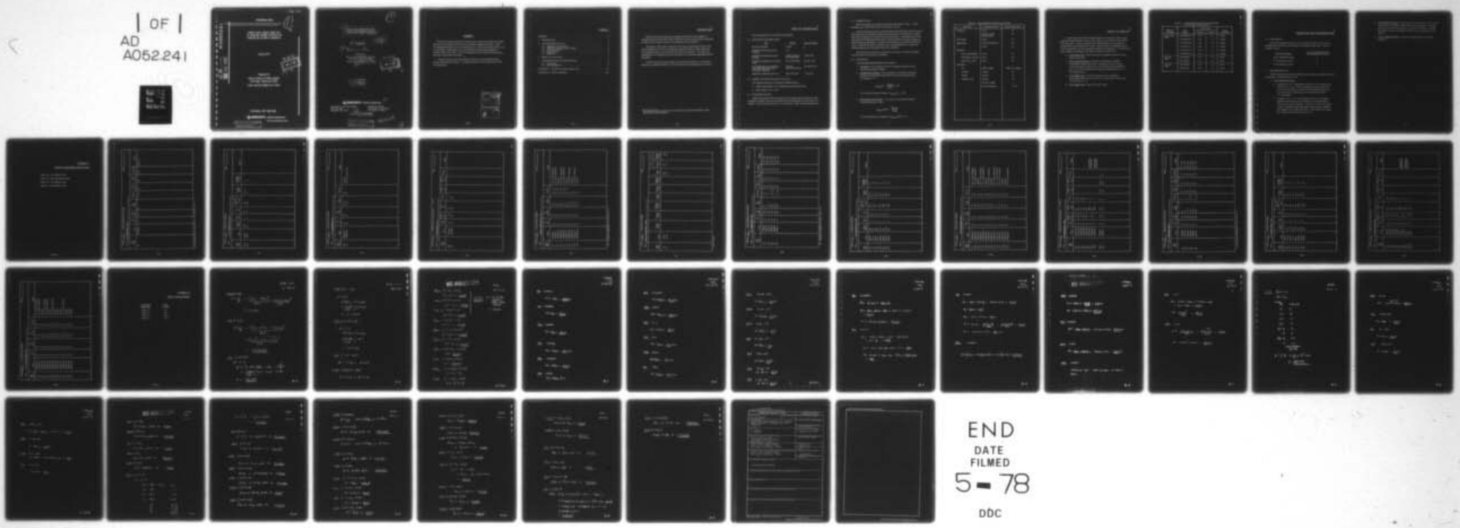

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TECHNICAL NOTE

WORST-CASE STRESS ANALYSIS OF RECEIVER POWER SUPPLIES IN TORPEDO MK 46 MOD 5 (NEARTIP)

August 1977

Prepared for

NAVAL OCEAN SYSTEMS CENTER
San Diego, California 92152

Under Contract N00123-76-C-0797

Publication W77-1640-TN02

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SUMMARY

A worst-case stress analysis of receiver power supplies in Torpedo Mk 46 Mod 5 (NEARTIP) was performed to identify any component application problems. Of the 97 components analyzed, none are overstressed (i.e., stress ratio greater than 1), and 10 exceed their recommended stress ratio based upon the derating guidelines of NAVSEA 0967-LP-597-1010. Of the 10 components, six had voltage-related and four had power-related stress problems.

ARINC Research recommends corrective action on the six components with voltage-related stress problems. No immediate action is recommended for the other four components.

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1
INTRODUCTION

ARINC Research Corporation is conducting a worst-case stress analysis of selected circuits of Torpedo Mk 46 Mod 5 (NEARTIP) to help ensure that the components selected for use in those circuits are not degrading system reliability. *

The purpose of this report, prepared for the Naval Ocean Systems Center under Contract N00123-76-C-0797, is to document component stresses, stress ratios, and other application factors of the NEARTIP receiver power supplies. The values presented herein were obtained from stress calculations on electronic components of these assemblies.

Ground rules for the stress analysis are presented in Section 2. Results of the analysis are presented in Section 3, and conclusions and recommendations in Section 4.

*The analysis was not, in fact, purely worst-case since nominal resistance values were used for all calculations.

2
ANALYSIS GROUND RULES

The following ground rules applied to this analysis.

2.1 APPLICABLE DOCUMENTATION

Title	Number	Date or Revision
Receiver Assembly	323890	A
NEARTIP Environmental Test Program	N/A	1
NEARTIP Component Tolerance Catalog	ARINC Research W76-1640-TN01	August 1976
Reliability Prediction of Electronic Parts	MIL-HDBK-217B	20 Sept. 1974
Parts Application and Reliability Information Manual for Navy Electronic Equipment	NAVSEA 0967-LP-597-1010	November 1975
Capacitors, Selection and Use of	MIL-STD-198C	7 July 1975

2.2 AMBIENT TEMPERATURE/INPUT VOLTAGE

The following system and environment conditions applied:

a. Ambient temperature = 70°C (maximum system specification)

b. Input voltage = 30 ± 1.5 Vdc

2.3 COMPONENT VALUES

Nominal component values were used for all resistance stress calculations since variations in resistor values due to tolerances do not significantly affect the stress calculations. The worst-case value at 70°C was used for all other component parameters.

2.4 STRESS VALUES

Stress calculations were made for the parameters shown in Table 1. These parameters are from NAVSEA 0967-LP-597-1010, Table B.

NOSC directed that the above-referenced NAVSEA document be utilized to assure that parameters and derating guidelines used in this study were selected in a manner that could be supported by recognized naval documentation. This handbook was developed by the Naval Ship Engineering Center to instruct design and project engineers in the meaning of and guidelines for electrical and electronic part and device standardization, reliability and quality screening levels, design applications, derating, and electrical parameters affecting part and device reliability.

Since none of the transistors evaluated have heat sinks, a thermal resistance was not required for the power calculations.

2.5 DEFINITIONS

The following definitions applied to this analysis:

a. Overstress — The condition in which a component exceeds any of its maximum parameteric ratings.

b. Recommended Derating — The percentage of a component's maximum parametric rating that NAVSEA 0967-LP-597-1010 recommends not be exceeded, i.e.:

$$P_{stress}(\%) = \frac{P_{actual}}{P_{rated}} \times 100$$

For wirewound accurate resistors, $P_{stress}(\%) = 40\%$.

c. Recommended Stress Ratio — The same as recommended derating, except expressed as a ratio:

$$P_{stress}(\text{ratio}) = \frac{P_{actual}}{P_{rated}}$$

For wirewound accurate resistors, $P_{stress}(\text{ratio}) \leq 0.4$.

TABLE 1. RECOMMENDED DERATING FACTORS

Part Type	Derating Parameter	Derated Value (Pct.)
Transistor	Power	40
	Junction voltage (steady state)	75
Zener diode	Power	50
Signal diode	Current (continuous)	60
	Power	50
Resistors:		
Film, high stability	Power	40
Wirewound, accurate	Power	40
Wirewound, power	Power	40
Capacitors:		
All	Ripple voltage	(Adhere to rating)
Ceramic	Voltage	50
Plastic	Voltage	50
Tantalum solid	Voltage	50
	Reverse voltage	0
	Circuit impedance	$>3\ \Omega/v$

3
RESULTS OF ANALYSIS

A worst-case stress analysis using the ground rules defined in Section 2 was performed on the NEARTIP receiver power supply, part of NAVORD Dwg. 3235890 (A3A1 thru A3A4). Table 2 summarizes the analytical data on components that exceeded their recommended stress ratios. Stress data for all components is presented in Appendix A, and the associated calculations in Appendix B. For the receiver power supplies, the findings of the study are summarized as follows:

a. Power Supply A3A1 – None of the seven components exceeds its recommended stress ratio.

b. Power Distribution A3A2 – Six of the 12 components exceed the recommended voltage stress ratio. Capacitors C2 thru C7 have a worst-case applied voltage ratio of 0.63 versus the recommended 0.5. (C2, C3, C5, C6 are polarized solid tantalum capacitors and C4, C7 are ceramic types.)

c. Power Supply A3A3 – Of the 38 components, two exceed their recommended power stress ratio of 0.4. Q6 has a power stress ratio of 0.44 and Q8 of 0.47.

d. Power Supply A3A4 – Same as for A3A3, above.

TABLE 2. COMPONENTS WITH STRESS PROBLEMS IN RECEIVER POWER SUPPLY

Receiver Assembly	Part Number	Stress Ratio		Stress Parameter
		Existing	Recom.	
Power Distr. A3A2	C2-M39003/01	0.63	0.5	Voltage
	C3-M39003/01	0.63	0.5	Voltage
	C4-M39014/01	0.63	0.5	Voltage
	C5-M39003/01	0.63	0.5	Voltage
	C6-M39003/01	0.63	0.5	Voltage
	C7-M39014/01	0.63	0.5	Voltage
15V Reg. A3A3	Q6-2N3635A	0.44	0.4	Power
	Q8-2N3019	0.47	0.4	Power
15V Reg. A3A4	Q6-2N3635A	0.44	0.4	Power
	Q8-2N3019	0.47	0.4	Power

4
CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

Of the 89 components analyzed in the receiver power supply, none are overstressed and 10 are stressed beyond their recommended stress ratio. They are located as follows:

Receiver Assembly	No. of Components Stressed Beyond Recommended Value
Power distribution (A3A2)	6
15 volt Regulator (A3A3)	2
15 volt Regulator (A3A4)	2

4.2 RECOMMENDATIONS

ARINC Research recommends the following with respect to components stressed beyond their recommended stress ratios:

a. Power Distribution (A3A2).

1) Capacitors C4, C7: Change these CKR05 50V, 0.1 uf capacitors to CKR06, 100V, 0.1 uf. This will reduce the existing stress ratio of 0.63 to 0.32, which is well below the recommended ratio of 0.5. For the two types, lead spacing is the same but the CKR06 is $\approx$0.1 inch longer.

2) Capacitors C2, C3, C5, C6: Determine if a 15 uf, 75V tantalum capacitor can be used in place of the 22 uf, 50V tantalum types. The case size would be the same. If the 15 uf is of too low a value, it may be possible to parallel an extra 15 uf capacitor to maintain the original 44 uf of $C2 \| C3$ and $C5 \| C6$. Either solution will reduce the voltage stress level from 0.63 to 0.32.

b. 15 Volt Regulator (A3A3). Since Q6 and Q8 each has a power stress ratio of less than 0.5, only slightly higher than the recommended 0.4, no change action is recommended at this time. In any future redesign, increasing R37 and R34 to 250Ω would reduce the stress ratios on Q6 and Q8 to less than 0.4.

c. 15 Volt Regulators (A3A4). The same recommendations as for A3A3 apply here.

APPENDIX A

NEARTIP COMPONENT STRESS DATA

Table A-1: 15V Regulator A3A1

Table A-2: Power Distribution A3A2

Table A-3: 15V Regulator A3A3

Table A-4: 15V Regulator A3A4

TABLE A-1 . SEMICONDUCTOR STRESS

Date ______

Unit 15 V REGULATOR, A3A1

Ref. Des.	Type	T_A (°C)	P_R (mW)	P_A (mW)	P_A/P_R	BV_X (volts)	V_X (volts)	V_X/BV_X	Notes
Q3	2N2905A	70	450	38	.1 (1)	60	31	.52	VX= VCE

(1) ANY STRESS RATIO LESS THAN .1 IS ROUNDED OFF TO .1

TABLE A-1. RESISTOR STRESS

Date

Unit 15 V REGULATOR, A3A1

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R11	RLR20	1.8K	2	70	500	47.8	.1	
R12	RLR20	15K	2	70	500	31	.1	

TABLE A-1. CAPACITOR STRESS

Date ________

Unit 15 V REGULATOR A3A1

Ref. Des.	Type	T_A (°C)	V_R (volts)	V_A (volts)	V_A/V_R	Notes
C24	M39014/01	70	50	16.32	.33	Ceramic
C35	M39003/01	70	35	16.32	.47	Pol Solid Tantalum

TABLE A-1 . SEMICONDUCTOR STRESS - DIODES

Date ______

Unit 15 V REGULATOR A3 A1

Ref. Des.	Type	T_A (°C)	ACTUAL P (mW)	RATED P (mW)	P_A/P_R	ACTUAL I (mA)	RATED I (mA)	I_A/I_R	Notes
VR1	1 N5530B	70	15.7	347	.1				
VR2	1 N5535B	70	84	347	.24				

TABLE A-2. CAPACITOR STRESS

Date ______

Unit POWER DISTRIBUTION, A3A2

Ref. Des.	Type	T_A (°C)	V_R (volts)	V_A (volts)	V_A/V_R	Notes
C2	M39003/1	70	50	31.5	.63 (1)	Pol Solid Tantalum
C3	M39003/1	70	50	31.5	.63 (1)	Pol Solid Tantalum
C4	M39014/01	70	50	31.5	.63 (1)	Ceramic
C5	M39003/01	70	50	31.5	.63 (1)	Pol Solid Tantalum
C6	M39003/01	70	50	31.5	.63 (1)	Pol Solid Tantalum
C7	M39014/01	70	50	31.5	.63 (1)	Ceramic
C8	M39003/01	70	35	15.75	.45	Pol Solid Tantalum
C9	M39014/01	70	50	15.75	.32	Ceramic
C10	M39003/01	70	35	15.75	.45	Pol Solid Tantalum
C11	M390014/01	70	50	15.75	.32	Ceramic

(1) EXCEEDS RECOMMENDED STRESS RATIO OF .6

TABLE A-2 . MAGNETIC STRESS Date ____________

Unit Power Distribution, A3A2

Ref. Des.	Type	P_{rated} (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	V_{rated} (volts)	V_{actual} (volts)	$\frac{V_{actual}}{V_{rated}}$	* I_{rated} MA	T_A = 70• C I_{actual} MA	T_A = 70• C $\frac{I_{actual}}{I_{rated}}$
L1	LT10K							400	70	.18
L2	LT10K							400	70	.18

* Test Current

TABLE A-3. SEMICONDUCTOR STRESS

Date ______

Unit 15 V REGULATORS A3A3

Ref. Des.	Type	T_A (°C)	P_R (mW)	P_A (mW)	P_A/P_R	BV_X (volts)	V_X (volts)	V_X/BV_X	Notes
Q2	2N2905A	70	450	76	.17	60	31	.52	VX = VCE
Q3	2N2222A	70	350	76	.22	60	31	.52	VX = VCE
Q5	2N2222A	70	350	14.6	.1	60	31	.52	VX = VCE
Q6	2N3635A	70	630	280	.44 (1)	140	31	.22	VX = VCE
Q7	2N2905A	70	450	14.6	.1	60	31	.52	VX = VCE
Q8	2N3019	70	590	280	.47 (1)	80	31	.39	VX= VCE

(1) EXCEEDS RECOMMENDED STRESS RATIO OF .4

TABLE A-3. RESISTOR STRESS

Date ______________

Unit 15V REGULATORS, A3A3

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R27	RLR07C	51K	2	70	250	92.0	.37	
R28	RLR20	910	1	70	500	94.7	.19	
R30	RLR07C	51K	2	70	250	92.0	.37	
R31	RLR20	910	1	70	500	94.7	.19	
R33	RLR07C	5.6K	2	70	250	18.4	.1	
R34	RLR32C	200	2	70	1000	190	.19	
R36	RLR07C	5.6K	2	70	250	18.4	.1	
R37	RLR32C	200	2	70	1000	190	.19	

TABLE A-3. CAPACITOR STRESS Date

Unit 15V REGULATORS, A3A3

Ref. Des.	Type	T_A (°C)	V_R (volts)	V_A (volts)	V_A/V_R	Notes
C9	M390031/01	70	20	9.8	.49	Pol. Solid Tantalum
C10	M39003/01	70	35	16.3	.47	Pol Solid Tantalum
C11	M39014/01	70	50	16.3	.33	Ceramic
C12	M39003/01	70	20	9.8	.49	Pol. Solid Tantalum
C13	M390031/01	70	35	16.3	.47	Pol. Solid Tantalum
C14	M39014/01	70	50	16.3	.33	Ceramic
C23	M39003/01	70	35	17.3	.49	Pol Solid Tantalum
C24	M39014/01	70	50	17.3	.35	Ceramic
C25	M39003/01	70	50	7.3	.15	Pol. Solid Tantalum
C26	M39014/01	70	50	7.3	.15	Pol. Solid Tantalum
C27	M39003/01	70	35	17.3	.49	Pol Solid Tantalum
C28	M39014/01	70	50	17.3	.35	Ceramic
C29	M39003/01	70	50	7.3	.15	Ceramic
C30	M39014/01	70	50	7.3	.15	Pol Solid Tantalum

TABLE A-3 . SEMICONDUCTOR STRESS - DIODES

Date ____________

Unit 15V REGULATORS, A3A3

Ref. Des.	Type	T_A (°C)	ACTUAL P (mW)	RATED P (mW)	P_A/P_R	ACTUAL I (mA)	RATED I (mA)	I_A/I_R	Notes
VR3	TX1N5530B	70	41.7	347	.12				
VR4	TX1N5535B	70	110	347	.32				
VR5	TX1N5530B	70	41.7	347	.12				
VR6	TX1N5535B	70	110	347	.32				
VR7	TX1N5535B	70	29.5	347	.1				
VR8	TX1N4964	70	-	5000	.1				overvoltage protection
VR9	TX1N5535B	70	29.5	347	.1				
VR10	TX1N4964	70	-	5000	.1				overvoltage protection
CR11	TX1N914	70	1.8	175	.1	1.8	52.5	.1	
CR12	TX1N914	70	1.8	175	.1	1.8	52.5	.1	

TABLE A-4. SEMICONDUCTOR STRESS Date ______

Unit 15 V REGULATOR A3A4

Ref. Des.	Type	T_A (°C)	P_R (mW)	P_A (mW)	P_A/P_R	BV_X (volts)	V_X (volts)	V_X/BV_X	Notes
Q2	2N2905A	70	450	76	.17	60	31	.52	VX = VCE
Q3	2N2222A	70	350	76	.2	60	31	.52	VX = VCE
Q5	2N2222A	70	350	14.6	.1	60	31	.52	VX = VCE
Q6	2N3635A	70	630	279	.44 (1)	140	31	.22	VX = VCE
Q7	2N2905A	70	450	14.6	.1	60	31	.52	VX = VCE
Q8	2N3019	70	590	279	.47 (1)	80	31	.39	VX = VCE

(1) EXCEEDS RECOMMENDED STRESS RATIO OF .4

TABLE A-4 . RESISTOR STRESS

Date ______

Unit 15 V REGULATORS, A3A4

Ref. Des.	Type	Value (ohms)	Tol. (%)	T_A (°C)	P_{rated} @ Spec. T_A (mW)	P_{actual} (mW)	$\frac{P_{actual}}{P_{rated}}$	Notes
R27	RLR07C	5.1K	2	70	250	92	.37	
R28	RLR20	910	1	70	250	94.7	.38	
R30	RLR07C	5.1K	2	70	250	92	.37	
R31	RLR20	910	1	70	250	94.7	.38	
R36	RLR07	5.6K	2	70	250	18.4	.1	
R37	RLR32C	200	2	70	1000	198	.20	
R39	RLR32C	5.6K	2	70	250	18.4	.1	
R40	RLR32C	200	2	70	1000	198	.20	

TABLE A-4 . SEMICONDUCTOR STRESS - DIODES

Date ______________

Unit 15 V REGULATORS A3A4

Ref. Des.	Type	T_A (°C)	ACTUAL P (mW)	RATED P (mW)	P_A/P_R	ACTUAL I (mA)	RATED I (mA)	I_A/I_R	Notes
VR3	1N5530B	70	41.7	347	.12				
VR4	1N5535B	70	110	347	.32				
VR5	1N5530B	70	41.7	347	.12				
VR6	1N5535B	70	110	347	.32				
VR7	1N5535B	70	29.5	347	.1				
VR8	1N4964	70	≃0	5000	.1				OVERVOLTAGE PROTECTION
VR9	1N5535B	70	29.5	347	.1				
VR10	1N4964	70	≃0	5000	.1				OVERVOLTAGE PROTECTION
CR11	1N914	70	1.81	175	.1				
CR12	1N914	70	1.81	175	.1				

TABLE A-4. CAPACITOR STRESS

Date ______

Unit 15 V REGULATORS A3A4

Ref. Des.	Type	T_A (°C)	V_R (volts)	V_A (volts)	V_A/V_R	Notes
C13	M39003/01	70	20	9.8	.49	Pol Solid Tantalum
C14	M39003/01	70	35	16.3	.47	Pol Solid Tantalum
C15	M39014/01	70	50	16.3	.33	Ceramic
C16	M39003/01	70	20	9.8	.49	Pol Solid Tantalum
C17	M39003/01	70	35	16.3	.47	Pol Solid Tantalum
C18	M39014/01	70	50	16.3	.33	Ceramic
C19	M39003/01	70	35	17.32	.49	Pol Solid Tantalum
C20	M39014/01	70	50	17.32	.35	Ceramic
C21	M39014/01	70	50	25.2	.50	Ceramic
C22	M39014/01	70	50	25.2	.50	Ceramic
C23	M39003/01	70	35	17.32	.49	Pol Solid Tantalum
C24	M39014/01	70	50	17.32	.35	Ceramic
C25	M39014/01	70	50	25.2	.50	Ceramic
C26	M39014/01	70	50	25.2	.50	Ceramic

APPENDIX B

STRESS CALCULATIONS

Calculations Supporting:	Start on Page:
Table A-1	B-3
Table A-2	B-5
Table A-3	B-7
Table A-4	B-19

A3A1 F1

(1 of 2)

R12 (15K)

$$P = \frac{E^2}{R} = \frac{(V_{SS} - V_{VR1})^2}{R12} = \frac{(31.5 - 9.8)^2}{15K}$$

21.8

$$= 31\ MW$$

R11 (1.8K)

$$P = \frac{E^2}{R} = \frac{(V_{SS} - V_{R12} - V_{BE\,Q3})^2}{R11}$$

9.28

$$= \frac{(31.5 - 21.8 - .42)^2}{1.8K}$$

$$= \underline{\underline{47.8\ MW}}$$

Q3 (2905A)

$$P = I\ E$$

$$P = (I_{R11})(V_{SS} - V_{R11} - V_{VR2})$$

$$= \frac{9.28V}{1.8K}(31.5 - 9.28 - 14.76)$$

$$P = \underline{\underline{38\ MW}}$$

VR1 (1N5530B)

$$P = IE$$
$$= (I_{R12})(E_{VR1})$$
$$= \left(\frac{21.8V}{15K}\right)(10.95)$$
$$= 15.7\,MW$$

VR2 (1N5535B)

$$P = IE$$
$$= (I_{R11})(E_{VR2})$$
$$= \left(\frac{9.28V}{1.8K}\right) 16.32$$
$$= 84\,MW$$

C24 (1UF 50V)

$$V = V_{VR2} = 16.32V$$

C35 (6.8UF 35V)

$$V = V_{C24} = 16.32\,V$$

C2 (22 μF, 50V)

$V = V_{SS} = \underline{31.5V}$

C3 (22 μF, 50V)

$V = V_{SS} = \underline{31.5V}$

C4 (.1 μF, 50V)

$V = V_{SS} = \underline{31.5V}$

C5 (22 UF, 50V)

$V = V_{SS} = \underline{31.5V}$

C6 (22 UF, 30V)

$V = V_{SS} = \underline{31.5V}$

C7 (.1 UF, 50V)

$V = V_{SS} = \underline{31.5V}$

C8 (47 UF, 35V)

$V = \underline{15.75}V$

C9 (.1 μF, 50V)

$V = \underline{15.75}V$

C10 (47 μF, 35V)

$V = 15.75V$

C11 (.1 μF, 50V)

$V = 15.75 V$

L1, L2 (LT10K) I ~ I of 15V regulator (A3A1 + A3A3 + A3A4)

~ 70 mA

<u>Q5</u> 2N2222A

$P \simeq P_{Q7} = \underline{\underline{14.6\,mW}}$

<u>Q3</u> 2N2222A

$P \simeq P_{Q2} = \underline{\underline{76\,mW}}$

<u>Q6</u> 2N3635A

$P \simeq P_{Q8} = \underline{\underline{280\,mW}}$

<u>VR7</u> 1N5535B

$P \simeq P_{VR9} = \underline{\underline{29.5\,mW}}$

<u>VR6</u> 1N5535B

$P \simeq P_{VR4} = \underline{\underline{110\,mW}}$

<u>VR8</u> 1N476A

$P \simeq P_{VR10} \cong 0$

VR5 1N5530B

$P \simeq P_{VR5} = \underline{41.7\,mW}$

CR11 1N914

$P \simeq P_{CR12} = \underline{1.81\,mW}$

R30 5.1K

$P \simeq P_{R27} = \underline{92\,mW}$

R33 5.6K

$P \simeq P_{R36} = \underline{18.4\,mW}$

R34 200 Ω

$P \simeq P_{R37} = \underline{190\,mW}$

R31 910 Ω

$P = P_{R28} = \underline{97.7\,mW}$

C23 5.6 μf, 35V

$V = V_{C27} = 17.32V$

C24 0.1μf, 50V

$V = V_{C28} = 17.32V$

C25 22μf, 50V

$V = V_{C29} = 7.3V$

C26 0.1μf, 50V

$V = V_{C30} = 7.3V$

C12 27μf, 20V

$V = V_{C9} = 9.82V$

C13 47μf, 35V

$V = V_{C10} = 16.32V$

C14 0.1μf, 50V

$V = V_{C11} = 16.32V$

Q7 2N2905A

$P \approx I_c V_{CE} \approx I_{R36} V_{CE}$

$V_C = V_{VR9} + V_{CR12} - V_{R36} = 16.32 + 1 - 9.25$
$= \underline{8.07V}$

$P \approx 1.81\,mA\,(8.07) = \underline{14.6\,mW}$

Q8 2N3019

$V_C = 30F3 - V_{R37} = 31.5 - 31\,mA\,(200)$
$= 31.5 - 6 = -\underline{25.5}$

$V_E \approx V_{VR7} + V_{CR12} + V_{BE} = 16.32 + 1 - 1 = \underline{16.32}$

$P \approx I_c V_{CE} \approx I_{R37} V_{CE} = 31\,mA\,(25.5 - 16.32)$
$= \underline{280}$

+15V1 ⊕V2
A3A3
(2 of 7)

Q2 2N2905A

$V_E = V_{R27} + V_{BE\,Q2} = 21.68 + 0.57 = \underline{22.25}$

$V_C = V_{VR4} = \underline{14.76}$

$V_{CE} = 22.25 - 14.76 = \underline{7.49}V$

$I_C \cong I_{R28} = \frac{30F3 - V_E}{R28} = \frac{31.5 - 22.25}{910} = \underline{10.2MA}$

$P = 10.2MA(7.49) = \underline{\underline{76}}$ MW

VR4 1N5535B

$P = (I_{C\,Q2} - I_{LOAD}) = (10.2 - 3.6)(16.32) = \underline{\underline{110MW}}$

+15V/4/2
(3057)

<u>VR3</u> 1N5530B

$I \approx I_{R27} = \frac{21.68}{5.1K} = \underline{4.25}\ \text{mA}$

$P = 4.25\ \text{mA}\ (9.82\ \text{V}) = \underline{\underline{41.7\ \text{mW}}}$

<u>VR9</u> 1N5535B

$P = I_{R36}\ (V_{VR9}) = 1.81\ \text{mA}\ (16.32) = \underline{\underline{29.5\ \text{mW}}}$

<u>CR12</u> 1N914

$P = I_{R36}\ (V_{CR12}) = 1.81\ \text{mA}\ (1.0) = \underline{\underline{1.81\ \text{mW}}}$

<u>VR10</u> 1N4964

NORMALLY OFF OVER VOLTAGE PROTECTION

$P \approx 0$

R27 5.1K

$V = +30F3 - V_{VR3} \approx +30VDC - V_{VR3}$

$= 31.5 - 9.82 = \underline{21.68 V}$

$P = \frac{21.68^2}{5.1K} = \underline{\underline{92 mW}}$

R36 5.6K

$I \cong \frac{V_{VR3} - V_{BEQ7}}{R36} = \frac{\overset{9.25}{9.82}\ 0.57}{5.1K} = \underline{1.81 MA}$

$P = 1.81MA^2 (5.6K) = \underline{\underline{18.4 MW}}$

R37 (200 Ω)

$I = I_L$

LOAD	
A1	2.65 mA
U1	8
U2	8
U3	2
U4	2
A2 A	2
B	2
AA3 A	1.75
B	1.75
	31 mA

$$P = I^2 R = (31 \cdot 10^{-3})^2\ 200$$

$$= \underline{190\ mW}$$

R28 910 Ω

SEE Q2

$P = 10.2\,mA^2(910) = \underline{94.7\,mW}$

C10 47μf, 35V

$V = V_{VR4} = \underline{16.32V}$

C11 0.1, 50V

$V = V_{C10} = \underline{16.32V}$

C9 27μf, 20V

$V = V_{VR3} = \underline{9.82V}$

C27 5.6 uf, 35V

$V = V_{R9} + V_{CR12} = 16.32 + 1 = \underline{17.32\,V}$

C28 0.1 uf, 50V

$V = V_{C27} = \underline{17.32}$

C29 27 uf, 50V

$V = V_{R37} = 36.5\,mA\,(200\,\Omega) = \underline{7.3\,V}$

C30 .1 uf, 50V

$V = V_{C29} = \underline{7.3\,V}$

BEST AVAILABLE COPY

A3A4
+30F4, [illegible]
(1 of 6)

R27 (5.1K)

$P \simeq$ R27, A3A3 $\simeq$ 92 MW

R28 (910 Ω)

$P \simeq$ R28, A3A3 $\simeq$ 94.7 MW

R30 (5.1K)

$P \simeq$ R30, A3A3 $\simeq$ 92 MW

R31 (910)

$P \simeq$ R30, A3A3 $\simeq$ 94.7 MW

R36 (5.6K)

$P \simeq$ R33, A3A3 $=$ 18.4 MW

R37 (200 Ω)

$P = I^2 R$

$I_1 =$	AR2	A, B	4 MA
$I_2 =$	AR3		1.5 MA
$I_3 =$	AR4		2 MA
$I_4 =$	AR1		4 MA
	U1		8 MA
	U2		8 MA
	U3		2 MA
	U3		2 MA
			31.5 MA

$$P = I^2 R = (31.5\ 10^{-3})^2\ 200$$
$$= \underline{\underline{198\ mW}}$$

<u>R39</u> (5.6K)

$P\ R39 \approx R33, A3A3 \approx \underline{\underline{18.4\ mW}}$

<u>R40</u> (200 Ω)

$P\ R40 \approx P\ R37 \approx \underline{\underline{198\ mW}}$

<u>VR3</u> (IN5530B)

$P_{VR3} \approx P_{VR3}, A3A3 \approx \underline{\underline{41.7\ mW}}$

<u>VR4</u> (IN5535B)

$P_{VR4} \approx P_{VR4}, A3A3 \approx \underline{\underline{110\ mW}}$

<u>VR5</u> (IN5530B).

$P_{VR5} \approx P_{VR5}, A3A3 \approx \underline{\underline{41.7\ mW}}$

<u>VR6</u> (IN5535B)

$P_{VR6} \approx P_{VR6}, A3A3 \approx \underline{\underline{110\ mW}}$

<u>VR7</u> (IN5535B)

$P_{VR7} \approx P_{VR9}, A3A3 \approx \underline{\underline{29.5\ mW}}$

A3A4

(3 of 6

VR8 (1N4964)

$P \simeq \underline{\underline{0}}$ overvoltage protection

VR9 (1N5535B)

$P \simeq P_{VR9, A3A3} \simeq \underline{\underline{29.5\ MW}}$

VR10 (1N 4964)

$P \simeq 0$ overvoltage protection

CR11 (1N 914)

$P \simeq P_{CR12, A3A3} \simeq \underline{\underline{1.81\ MW}}$

CR12 (1N914)

$P \simeq P_{CR12, A3A3} \simeq \underline{\underline{1.81\ MW}}$

C13 (27 UF, 20V)

$V = V_{VR3} = \underline{\underline{9.8\ V}}$

C14 (47 UF, 35V)

$V = V_{VR4} = \underline{\underline{16.3\ V}}$

C15 (.1 UF, 50V) -

$V = V_{VR4} = \underline{\underline{16.3\ V}}$

C16 (27 UF, 20V)

$V = V_{VR5} = \underline{\underline{9.82\ V}}$

C17 (47 UF, 35 V)

$$V_{C17} = V_{VR6} = \underline{\underline{16.32V}}$$

C18 (.1 UF, 50 V)

$$V_{C18} = V_{VR6} = \underline{\underline{16.32\ V}}$$

C19 (5.6 μF, 35 V)

$$V_{C19} = V_{VR7} + V_{CR11}$$

$$= 16.32V + 1 = \underline{\underline{17.32}}$$

C20 (.1 UF, 50 V)

$$V_{C20} = V_{C19} = \underline{\underline{17.32V}}$$

C21 (22 UF, 50V)

$$V_{C21} = V_{S3} - V_{R37}$$

$$= 31.5 - (31.5\ mA)(200\Omega)$$

$$= \underline{\underline{25.2\ V}}$$

C22 (.1 UF, 50V)

$$V_{C22} = V_{C21} = \underline{\underline{25.2\ V}}$$

C23 (5.6 UF, 35V)

$$V_{C23} = V_{C19} = \underline{\underline{17.32V}}$$

C24 (.1UF, 50V)

$$V_{C24} = V_{C23} = \underline{\underline{17.32V}}$$

C25 (22 μF, 50V)

$$V_{C25} \approx V_{C21} = \underline{25.2V}$$

C26 (.1UF, 50V)

$$V_{C26} = V_{C25} = \underline{25.2V}$$

Q2 (2N2905A)

$$P_{Q2} \simeq P_{Q2,\,A3A3} = \underline{76\,mw}$$

Q3 (2N2222A)

$$P_{Q3} \simeq P_{Q2} = \underline{76\,mw}$$

Q5 (2N2222A)

$$P_{Q5} \simeq P_{Q5,\,A3A3} = \underline{14.6\,mw}$$

Q6 (2N3635)

$$P_{Q6} = I_C E_{CE} = (I_{R37})(V_{SS} - V_{R37} - V_{Q6E})$$

$$= 31.5mA(31.5V\ (31.5mA)(200\Omega) - V_{R9} - V_{CR12} + V_{BE\,Q6})$$

$$= 31.5mA(31.5V - (31.5mA)(200) - 16.32 - 1 + 1)$$

$$= (31.5mA)(8.88V)$$

$$= \underline{279\,mw}$$

Q7 (2N2905A)

$P_{Q7} \simeq P_{Q5} \simeq \underline{\underline{14.6\,mW}}$

Q8 (2N3019)

$P_{Q8} \simeq Q6 \simeq \underline{\underline{279\,mW}}$

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